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<p>(54) Title: MULTIDETERMINANT PEPTIDE ANTIGENS THAT STIMULATE HELPER T LYMPHOCYTE RESPONSE TO HIV IN A RANGE OF HUMAN SUBJECTS</p>			
<p>(57) Abstract</p> <p>This invention relates to the selection and preparation of synthetic peptides which stimulate helper T lymphocyte response to HIV in a wide range of human subjects. These multideterminant peptides are, therefore, useful for the production of vaccines against HIV infection and for diagnostic procedures to test for HIV seroconversion.</p>			

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**MULTIDETERMINANT PEPTIDE ANTIGENS THAT  
STIMULATE HELPER T LYMPHOCYTE RESPONSE  
TO HIV IN A RANGE OF HUMAN SUBJECTS**

**Related Applications**

5 This application is a continuation in part of U.S. application Serial Number 07/492,318, filed on 28-Feb-1990, and of U.S. application Serial Number 07/148,692, filed on 26-Jan-1988, both of which are hereby incorporated by reference.

10 **Field of the Invention**

The invention is directed to a method for the selection of peptides useful for production of vaccine(s) against HIV infection or as components of a therapeutic mixture or as components of a diagnostic 15 kit for HIV seroconversion. The instant application also describes a series of peptides selected by the method.

**Background of the Invention**

Whole virus vaccines against HIV, live attenuated 20 or killed offer the potential to stimulate immunity to the broadest array of antigenic determinants of the

virus. However, they also may contain structures developed by the virus to evade the immune system, such as suppressive epitopes or masking carbohydrates, or structures which elicit deleterious effects such as enhancing antibodies that increase viral infectivity (Takeda, A. et al. *Science* 242:580-583. (1988); Robinson, W.E.Jr. et al., *Proc. Nati. Acad. Sci. USA* 86:4710-4714 (1989); Robinson, W.E.,Jr. et al.; *Proc. Natl. Acad. Sci. USA* 87:3185-3189 (1990); Halstead, S.B. *Science* 239:476-481 (1988)) or antibodies or T cells that may contribute to immunodeficiency in the case of HIV (Weinhold, K.J. et al., *J. Immununol* 142:3091-3097 (1989); Siliciano, R-F. et al., *Cell* 54:561-575 (1988); Mittler, R.S. and M. K. Hoffmann, *Science* 245:1380-1382 (1989); Golding, H. et al., *J. Clin. Invest.* 83:1430-1435 (1989)). In addition, for a retrovirus such as HIV, concerns about the safety of live attenuated or even killed whole viral vaccines may make them unacceptable to many potential recipients. Purified subunit vaccines have less safety risk, but still may suffer from the other problems of whole virus vaccines. Indeed, because the virus has evolved to evade the immune system, evolution may have favored the development of viral proteins that are hardly optimal as vaccines. Thus, in contrast to enzymes which have been honed by evolution to be the best structures for catalyzing their reactions, viral proteins may leave the scientist with considerable opportunities to improve on nature for the development of better vaccines (Berzofsky, J.A., *J. Clin. Invest.* 82:1811-1817 (1988)).

To rationally design highly engineered synthetic or recombinant antiviral vaccines, one needs considerable knowledge about the workings of the immune system, and in particular, about the immune response to structures expressed by the virus. The present inventors have initiated such an approach by attempting to identify antigenic determinants recognized by cytotoxic T lymphocytes (CTL) (Takahashi, H. et al., *Proc. Natl. Acad. Sci. USA* 85:3105-3109 (1988); Takahashi, H. et al., *Science* 246:118-121 (1989); Takahashi, H. et al., *J. Exp. Med.* 170:2023-2035 (1989); Takahashi, H. et al., *J. Exp. Med.* 171:571-576 (1990); Hosmalin, A. et al., *Proc. Natl. Acad. Sci. USA* 87:2344-2348 (1990)) and by helper T cells that would be required for either a CTL or an antibody response (Cease, K.B. et al., *Proc. Natl. Acad. Sci. USA* 84:4249-4253 (1987); Berzofsky, J.A. et al., *Nature* 334:706-708 (1988); Clerici, M. et al., *Nature* 339:383-385 (1989); Hale, P.M. et al., *Internat. Immunol.* 1:409-415 (1989)). However, a potential problem with the use of any single antigenic determinant is that T cells recognize antigens in association with molecules encoded by the major histocompatibility complex (MHC) of the host, and the MHC molecules of any given individual will bind and present only a subset of potential antigenic determinants that could be recognized by the species as a whole (Benacerraf, B., *J. Immunol.* 120:1809-1812 (1978); Schwartz, R.H., *Annu. Rev. Immunol.* 3:237-261 (1985); Berzofsky, J.A., in "The Antigens". pp. 1 - 146, M. Sela, editor, c. 1987 by Academic Press, New York). This is true of humans as well as mice (Siliciano, R-F. et al., *Cell* 54:561-575 (1988);

Schrier, R.D. et al., *J. Immunol.* 142:1166-1176 (1989); Callahan, K.M. et al., *J. Immunol.* 144:3341-3346 (1990); Martin, R. et al., *J. Immunol.* 145:540-548 (1990); Martin, R. et al., *J. Exp. Med.* 173:19-24 (1991); Jaraquemada, D. et al., *J. Immunol.* 145:2880-2885 (1990)).

Therefore, in order to be useful in a broad outbred population such as humans, a vaccine should contain multiple such determinants. Only limited data exist to indicate how many such determinants would have to be included. Although some concern has been raised that the number might be impractical to achieve, some data exist to suggest that as few as four such determinants could elicit responses in 85-90% of outbred humans (Clerici, M. et al., *Nature* 339:383-385 (1989)). A few antigenic peptides have been identified that appear to be promiscuous in their recognition in association with many DR molecules (Sinigaglia, F. et al., *Nature* 336:778-780 (1988); Panina-Bordignon, P. et al., *Eur. J. Immunol.* 19:2237-2242 (1989)), perhaps because DR molecules share a conserved alpha chain, and in the mouse some determinants have been reported to be presented by three different I-A molecules that do not share alpha chains (Brett, S.J. et al., *J. Immunol.* 143:771-779 (1989)), or even by class II MHC molecules of different isotypes, such as I-A and I-E (Guillet, J.-G. et al., *Science* 235:865-870 (1987))). However, it is not clear how common such promiscuous epitopes are.

In the course of locating the major T-cell stimulatory sites of the HIV envelope, we observed that there were regions in the sequence that contained

multiple overlapping determinants seen by mice of different MHC haplotypes (Hale, P.M. et al., *Internat. Immunol.* 1:409-415 (1989)). Although the precise determinants seen by T cells of each strain of mouse differed, each multideterminant region contained determinants that could stimulate T cells of mice of three or four of the four MHC types tested. We, therefore, reasoned that peptides encompassing such multideterminant regions might be able to stimulate T cells of many or most haplotypes of mice, and hopefully also T cells of humans of many HLA types. Thus, such multideterminant peptides might provide a means to circumvent this problem of MHC restriction in the design of synthetic vaccines. The present applicants have, therefore, tested this hypothesis by constructing six synthetic peptides of 20-33 residues each that correspond to the six multideterminant regions of HIV envelope protein localized in the mouse (Hale, P.M. et al., *Internat. Immunol.* 1:409-415 (1989)), and tested these peptides for their ability to stimulate T-cell responses in mice immunized with recombinant gp160 and in peripheral blood lymphocytes of humans infected with HIV. Although not all of the peptides were as widely recognized as expected, several such peptides were identified that were broadly recognized by both murine and human T cells of multiple H-2 and HLA types. These peptides can also immunize mice for T-cell responses to the intact HIV envelope protein, and so are useful as valuable components of a synthetic vaccine, and responses to them are useful diagnostic or prognostic markers.

Summary of the Invention

It is one object of the present invention to demonstrate a process for the selection of synthetic peptides that are useful candidates for vaccines against HIV. Furthermore, a set of particular peptides are described that have demonstrated efficacy in the process above. Finally, the invention may find application in diagnostic and therapeutic settings.

Brief Description of the Drawings

10 Figure 1 shows the proliferative response of T cells from gp160-immune mice to the six cluster peptides.

15 Figure 2 shows the proliferation response to recombinant gp160 of T-cells isolated from the lymph nodes of mice immunized with cluster peptides.

Detailed Description of the Invention

20 The invention is described by means of several examples below. The examples are presented for purposes of illustration and are not to be construed as limiting the scope of the instant invention. It is understood that various modifications or changes in light of these examples will be suggested to persons skilled in the art and such are to be included within the spirit and purview of this application and within 25 the scope of the appended claims.

Example 1

30 Selection of peptides encompassing multideterminant clusters of HIV envelope that induce in vitro T-cell responses in mice of multiple MHC type and in a population of HIV seropositive humans.

1. Synthesis of peptides. The six cluster peptides are synthesized on an Applied Biosystems 430A automated peptide synthesizer using t-boc chemistry

(Stewart, J.M. and J.D. Young. "Solid Phase Peptide Synthesis", Pierce Chemical Company, Rockford, Illinois (1984)). The peptides are cleaved from the resin with HF and are initially purified by molecular exclusion chromatography (P4 biogel, BioRad). Reverse phase HPLC is employed to determine degree of purity and in cases requiring further purification. The HPLC separations are carried out on Waters  $\mu$ bondapack reverse phase C18 analytical and preparative columns.

5 The sequences of the peptides synthesized for the experiment are shown in Table 1 below:

10

Table 1. Sequences of Cluster Peptides

PCLUS1 (109-128)	EQMHEDIISLWDQSLKPCVK (SEQ ID 1)
15 PCLUS2 (324-356)	FVTIGKIGNMRQAHCNISRAKWNNTLKQIDSKL (SEQ ID 2)
PCLUS3 (428-451)	KQIINMWQEVGKAMYAPPISGQIR (SEQ ID 3)
PCLUS4 (483-506)	RDNWRSELYKYKVVKIEPLGVAPT (SEQ ID 4)
PCLUS5 (787-820)	RIVELLGRRGWEALKYWWNLLQYWSQELKNSAVS (SEQ ID 5)
20 PCLUS6 (828-860)	AVAEGTDRVIEVVQGAYRAIRHIPRRIQGLER (SEQ ID 6)

The peptides encompassed by the six cluster peptides are shown in Table 2 below:

Table 2. Sequences of Cluster Peptides  
and the Peptides They Encompass

5	PCLUS1 (109-128)	EQMHEDIISLWDQSLKPCVK EQMHEDIISLWDQSL QMHEDEIISLWDQSLK HEDIISLWDQSLK HEDIISLWDQSLR DIISLWDQSLKPCVK
10	HP-3 HP-4 HP-5 HP-6 HP-7	
	PCLUS2 (324-356)	FVTIGKIGNMRQAH(NIS)RAKWNNTLKQIDSKL FVTIGKIGNMRQAH RAKWNNTLKQIDSKL
15	HP-19 HP-20	
	PCLUS3 (428-451)	KQIINMWQEVGKAMYAPPISGQIR KQIINMWQEVGKAMYA NMWQEVGKAMYAPPI VGKAMYAPPISGQIR
20	HP-26 HP-28 HP-29	
	PCLUS4 (483-506)	RDNWRSELYKYKVVKIEPLGVAPT RDNWRSELYKYKVVK KYKVVKIEPLGVAPT
25	HP-30 HP-33	
	PCLUS5 (787-820)	RIVELLGRRGWEALKYWWNLLQYWSQELKNSAVS RIVELLGRRGWEALK KYWWNLLQYWSQELK LLQYWSQELKNSAVS
30	HP-47 HP-50 HP-51 HP-52 HP-53 HP-54 HP-55 HP-56	AVAEGTDRVIEVVQGAYRAIRHIPRRIQGLER AVAEGTDRVIEVVQG DRVIEVVQGAYRAIR VIEVVQGAYRAIRHI QGAYRAIRHIPRRI AIRHIPRRIQGLER

2. Mice. B10.BR/SgSn and B10.D2/nSn strains are obtained from The Jackson Laboratory (Bar Harbor, ME, USA). B10.S(9R) and B10A(5R) strains are bred in our colony from breeders obtained from J. Stimpfing and

5 Jackson Laboratories, respectively.

3. *gp160 preparation.* Recombinant gp160 is prepared from cells infected with recombinant baculovirus expressing the gene for gp160 of the HTLV-IIIB isolate of HIV-1 as described (Javaherian, K. et al., *Proc.*

10 *Natl. Acad. Sci. USA* 86:6768-6772 (1989)).

4. *T-cell proliferation assay* (Corradin, G., *J. Immunol.* 119:1048 (1977)). Mice are immunized subcutaneously in the tail with 20-30 µg recombinant gp160 emulsified 1:1 in complete Freund's adjuvant

15 The mice are sacrificed 8-11 days following immunization and their draining inguinal and periaortic lymph nodes are harvested and teased into single cell suspensions in complete T-cell medium (Matis, L.A. et al., *J. Immunol.* 130:1527-1535

20 (1983)). Aliquots consisting of  $4 \times 10^5$  cells are introduced into wells of 96-well flat-bottom culture plates containing various concentrations of the cluster peptides (2, 0.66, 0.22 µM final concentration in triplicate). After four days of incubation at 37°

25 in 5% CO<sub>2</sub>, tritiated thymidine (1 mCi) is added to all the wells. 24 hr later the cells are harvested on an automated harvesting device (Skatron) and thymidine incorporated into DNA determined by scintillation counting. The stimulation index is the ratio of cpm

30 incorporated in the presence of antigen to cpm incorporated by cells cultured with medium alone.

Each cluster peptide of Table 1 was synthesized and purified as described above and tested for the ability to stimulate T-cell proliferative responses of mice of the four MHC types noted that had been immunized with recombinant gp160. B10 congenic mice are used that differed only in their MHC type, but are otherwise genetically identical. The four mouse MHC types studied are chosen because they represent four independent MHC haplotypes that each express both an I-A and an I-E molecule, and differ from each other in both of these molecules. Thus the four strains together express eight different murine class II MHC molecules. It should be noted that the murine I-E molecules, like human DR molecules to which they are homologous, all share a conserved alpha chain, but differ in their beta chain, which accounts for all the polymorphism. Responses to most antigens differ among the several I-E and DR alleles, indicating the important role of the beta chain, despite the shared alpha chain.

Each peptide was studied in four independent experiments (or three for cluster peptide 3, which was synthesized last), and the results pooled by determining the geometric mean of the stimulation indices for a given peptide concentration in all four experiments. The results are presented in Figure 1, which shows the stimulation index as a function of peptide concentration in the culture, for 4 congenic strains of mice representing 4 distinct MHC haplotypes. Each value is the geometric mean stimulation index of 4 (or 3 in the case of cluster peptide 3) independent experiments. Although the results of the several experiments were qualitatively

similar, the absolute values of the stimulation indices varied sufficiently as to make error bars difficult to read on these plots. Instead, values for which the mean stimulation index of all experiments is statistically significantly different from background (1.0) as measured by a Student's t test ( $p < 0.05$ ) are indicated with an asterisk. Results were considered positive only if this statistic was significant and the mean stimulation index of all experiments was  $> 2$ . Cluster peptides 3, 4 and 6 were the only ones to elicit a positive response in mice of all four MHC haplotypes. Cluster peptide 6 stimulated most strongly in B10.BR and B10.A(5R) mice, and gave weaker but significantly positive and reproducible responses in B10.S(9R) and B10.D2. Cluster peptide 4 stimulated most strongly in B10.S(9R), but was significantly and reproducibly positive in the other strains as well. Cluster peptide 3 stimulated very strongly in B10.S(9R), and gave weak but statistically significant responses in the other three strains. The responses were more strongly positive in some experiments for these other strains, but some variability in magnitude of response reduced the geometric mean, although they remained statistically significant. These three peptides thus fulfill the predictions of the hypothesis (Hale, P.M. et al., *Internat. Immunol.* 1:409-415 (1989)) that by making an extended peptide encompassing overlapping antigenic determinants recognized by mice of multiple haplotypes, the resulting construct would be broadly recognized by all or most haplotypes.

The remaining three peptides elicited responses in fewer strains of mice than expected. Cluster

peptide 2 was strongly positive in only two strains, B10.D2 and B10.BR, despite the fact that all four strains had recognized at least one site encompassed within this multideterminant region in our earlier study (Hale, P.M. et al., *Internat. Immunol.* 1:409-415 (1989)). Similarly, cluster peptide 1 was recognized by one strain, B10.BR, strongly, and by another strain, B10.S(9R) only marginally, despite the fact that all four strains had recognized components of this multideterminant region. The most disappointing peptide was cluster peptide 5, which failed to elicit a significant response in three strains, and gave only a marginal response in the fourth strain B10.BR. These results suggest that the larger peptide is not simply the sum of its parts, but may fail to stimulate in strains that a smaller subcomponent would stimulate, perhaps because parts of the larger structure hinder interaction with MHC or T cell receptor, or because they cause the peptide to fold back on itself (Brett, S.J. et al., *J. Exp. Med.* 168:357-373 (1988); Gammon, G. et al., *Immunol. Rev.* 98:53-73 (1987); Vacchio, M.S. et al., *J. Immunol.* 143:2814-2819 (1989); Berzofsky, J.A. et al., *Immunol. Rev.* 106:5-31 (1988)) or because of different processing requirements.

5. *IL-2 production by human PBL.* For the assay of antigen-induced IL-2 production by human peripheral blood T cells, PBL from HIV-seropositive asymptomatic blood donors are separated on lymphocyte separation medium (LSM, Organon Teknica Corp, Durham, NC), washed twice, counted, and resuspended at  $3 \times 10^6$ /ml in RPMI 1640 (Gibco, Grand Island, NY) containing 50 U/ml

penicillin and 2 mM glutamine. In triplicate wells in a 96-well flat bottom plate (Costar, Cambridge, MA), 0.1 ml of PBL is added per well and cultured without stimulation or stimulated with: a) influenza A/Bangkok 5 RX73 (final dilution 1: 1000); b) PHA (Gibco) (antigen dilution 1:100); or c) cluster peptides at a final concentration of 2.5  $\mu$ M. Pooled AB+ plasma is added to each well (final dilution 1:20). The anti-IL-2 receptor antibody anti-Tac (obtained from Dr. T. A. 10 Waldmann, NCI) is added to each well at the initiation of culture (final concentration 5  $\mu$ M) in order to block IL-2 consumption. The supernatants of the cell cultures are harvested 7 d later and frozen at -20°C. The supernatant IL-2 activity is assessed as the 15 ability to stimulate the proliferation of the IL-2-dependent CTLL cell line as previously described (Clerici, M. et al., *J. Clin. Invest.* 84:1892-1899 (1989)).

Although prior publications demonstrate that many 20 peptides that elicit responses in murine T cells also do so with human T cells (Berzofsky, J.A. et al., *Nature* 334:706-708 (1988); Clerici, M. et al., *Nature* 339:383-385 (1989); Lamb, J.R. et al., *Nature* 300:66-69 (1982); Hurwitz, J.L. et al., *J. Immunol.* 133:3371-3377 (1984); Good, M.F. et al., *Science* 235:1059-1062 (1987); Good, M.F., *Proc. Natl. Acad. Sci. USA* 85:1199-1203 (1988)); Dontfrail, F. et al., *Mol. Biol. Med.* 5:185-196 (1988)), there were no data 25 on human T cells to some of the components of the cluster peptides. Therefore, the experiments leading 30 to the present invention were designed to test the hypothesis that peptides that elicit responses in mice of multiple MHC types were likely to elicit responses

in humans of multiple HLA types as well. It was known from earlier work that peptide envT2 (residues 112-124) contained within cluster peptide 1, peptide envT1 (residues 428-443) contained within cluster peptide 3, and peptide TH4.1 (residues 834-848, also known as HP53) contained within cluster peptide 6 all stimulated responses in 50-67% of HIV-infected human subjects who could still respond to positive-control recall antigens such as influenza A virus (flu) or tetanus toxoid (Clerici, M. et al., *Nature* 339:383-385 (1989)). However, we had no prior experience with peptides from these other multideterminant regions in humans. Because the proliferative and IL-2 productive responses to soluble protein antigens is lost early in HIV infection, frequently when patients are still asymptomatic and have normal CD4+ cell numbers (Clerici, M. et al., *Nature* 339:383-385 (1989); Clerici, M. et al., *J. Clin. Invest.* 84:1892-1899 (1989); Lane, H.C. et al., *New Engl. J. Med.* 313:79-84 (1985)), responses to flu and tetanus toxoid were used as positive controls in these experiments to exclude donors unresponsive to all such recall protein antigens.

All six cluster peptides were tested for the ability to stimulate IL-2 production by peripheral blood T cells from a series of HIV-seropositive but asymptomatic volunteers, as well as HIV-seronegative controls. All 15 seronegative controls responded to the control recall antigen influenza virus (flu), but only 42 of the 59 HIV-seropositive donors responded to flu. Because of our previous experience that seropositive donors who fail to respond to control recall protein antigens such as flu or tetanus toxoid

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also fail to respond to HIV peptides (Clerici, M. t al., *Nature* 339:383-385 (1989)), the 17 donors who failed to respond to flu were excluded from further study. Because some of the peptides had not been purified at the time some of the donors were available, these peptides were tested on cells from a subset of the donors. Results for the six cluster peptides in the 42 HIV-seropositive flu-positive donors and 15 control HIV-seronegative donors are given in Table 3, and summarized in Table 4.

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Table 3. IL-2 Production by T cells from HIV-  
seropositive and seronegative human blood donors

Donor Number	FLU	Cluster Peptide Number					
		1	2	3	4	5	6
HIV+							
Donors							
317	64.5	11.4(NS)	1.9	NT	NT	NT	29.7
453	91.4	5.0(NS)	30.2	NT	NT	NT	16.3
909	6.3	7.8	9.1	NT	2.3	2.8	9.4
360	4.0	2.7	2.2	NT	2.2	7.5	3.3
396	3.2	2.4	1.7	NT	1.4	2.3	3.1
131	8.2	.5	1.9	NT	1.2	.1	5.2
208	5.1	2.8	5.7	NT	9.0	9.4	.4
335	26.4	9.2	9.0	NT	.2	2.4	6.4
69	3.6	2.3	4.7	NT	1.0	2.1	1.6
556	3.4	4.0	.8	NT	.8	.8	1.5
212	37.9	21.9	13.1	NT	.2	.2	5.7
375	15.1	6.1	.8	NT	1.7	2.8	2.9
564	7.8	4.8	4.1	NT	8.4	1.8	1.0
83	26.5	2.7	13.3	NT	.6	36.3	14.4
621	112.3	54.8	39.1	NT	.5	1.3	2.2(NS)
920	5.5	2.1	1.7	NT	7.0	4.2	1.5
90	16.0	2.4	4.4	2.9	3.2	1.6	1.0
224	3.1	1.3	1.4	NT	1.3	2.5	3.0
430	7.9	3.1	2.8	NT	3.4	4.6	4.4
698	6.5	2.6	4.7	NT	1.0	1.3	1.2
399	6.7	1.7	1.4	NT	1.4	2.8	3.0
923	7.9	2.4	1.6	NT	.4	3.6	5.0
75	14.2	.8	5.4	NT	3.3	7.9	1.1
281	16.1	5.9	1.1	NT	12.2	6.3	5.1
357	26.1	2.0(NS)	5.8	NT	11.3	2.3(NS)	7.0
395	36.7	4.1	7.9	NT	3.8	11.7	5.8
916	36.2	12.0	2.7	NT	NT	NT	1.9
232	7.5	2.1(NS)	.3	NT	NT	NT	1.8
755	8.6	.5	.2	NT	NT	NT	54.9
193	22.3	1.4	13.2	NT	NT	NT	3.1
911	15.8	2.1	3.1	NT	NT	.9	1.7
419	12.9	.9	6.6	NT	NT	.3	.5
914	9.3	.4	.5	NT	4.9	1.4	NT
132	18.9	1.8	1.4	1.5	13.8	9.1	NT
504	20.4	5.3	13.8	9.6	9.7	.3	NT
933	17.7	9.6	1.4	7.7	NT	NT	NT
213	6.8	NT	NT	10.9	NT	NT	NT
421	12.7	NT	NT	1.7	NT	NT	NT
604	6.1	NT	NT	8.9	NT	NT	NT
851	5.6	NT	NT	8.1	NT	NT	NT
904	22.5	NT	NT				

	906	3.1	NT	NT	5.7	NT	NT	NT	NT
<b>HIV-CONTROLS</b>									
HC1	6.6	.8	1.0	NT	2.5	.2	.1		
HC2	8.4	.2	.4	NT	.4	.3	.6		
HC3	2.9	.3	.7	NT	.1	.7	1.1		
HC4	7.3	1.0	.9	NT	.5	.2	1.9		
HCS	10.9	.6	2.2	NT		.3	.7		
HC6	7.0	.7	.5	1.0	NT	1.1	1.0		
HC7	3.9	1.8	.9	.8	NT	1.4	.7		
HC8	4.4	.9	.8	.2	NT	.1	NT		
HC12	6.2	.7	.2	.9	1.0	.5	NT		
HCbb1	6.3	.7	.7	.4	.2	.7	.6	.4	
HCbb2	17.6	.2	.4		.2	.1	.4	.4	
HCbb3	5.5	.6	.1		.2	.7	.8	.5	
HCbb4	74.6	1.3	1.9	15.3	1.2	.2	.5	.7	
HCbb5	6.7	2.9			1.2	1.2	1.8	NT	
HCbb6	6.5	1.1	.8		1.2				

Values shown are stimulation indices for proliferation of an IL-2-dependent CTLL cell line in the presence of a 1:2 dilution of culture supernatant from triplicate cultures of PBL from the indicated donor with a 2.5  $\mu$ M concentration of the indicated peptide, as described above. All of the seropositive donors and controls studied were responsive to the positive control recall protein antigen flu. For a value to be considered positive, it had to simultaneously meet two criteria: 10 The replicates had to be statistically significantly different from the control replicates for that donor by Student's t test ( $p < 0.05$ ), and the stimulation index had to be greater than twice the medium control. Six cases marked NS were stimulation indices  $> 2.0$  15 which were not counted as positives because the

replicates were not statistically significant. In several cases with  $SI < 2.0$ , the replicates were significantly different from background, but these were not considered positive because of the low stimulation index. The requirement for both criteria is thus more conservative than using either alone.

Table 4. Summary of Human T-cell IL-2 Responses to Cluster Peptides

10	Cluster	Cluster	Cluster	Cluster	Cluster	Cluster
		Peptide 1	Peptide 2	Peptide 3	Peptide 4	Peptide 5
	HIV+FLU+	23/36	21/36	8/11	14/27	17/29
15	19/33					
	Donors	64%	58%	73%	52%	59%
						58%
	HIV-FLU+	1/15	2/15	0/10	1/11	0/14
	1/12					
20	Controls	7%	13%	0%	9%	0%
						8%

See legend to table 3 for criteria for positivity.

Table 5. HLA Typing of HIV-seropositive donors

Donor	HLA-A	HLA-B	HLA-C	DQ	DR
90	24, 29	7, 44	2, 3		
208	9 (23), 32	7, 17	3	1, 2	2, 3
281	23, 33	17	3	2	1, 3
375	2, 24	35, 61	2, 4	1	3
131	1, 3	7, 62	3	1, 3	2, 4
909	30, 33	17	3	1	1, 2
232	9, 31	14, 18	3	2, 3	3, 5
755	2, 28	35, 15	2, 3	1, 3	2, 4
75	30	7, 18	2		
360	2, 31	51	2		
317	28	12	3	1, 2	2, 4
395	1, 3	7, 8	-		

All six cluster peptides stimulated IL-2 production in more than half of the HIV-seropositive, flu-positive donors. Cluster peptides 1 and 3 were most broadly recognized, giving responses in 64% and 73% of the donors. Cluster peptides 2, 5, and 6 were close seconds, positive in 58, 59, and 58% of the donors, respectively. The least broadly recognized was cluster peptide 4, but even this stimulated 52% of the donors. In contrast, none or only one of the control seronegative donors responded to any of the peptides except cluster peptide 2, which stimulated 2 of the 15 control donors (13%). Thus, none of the peptides was nonspecifically mitogenic. The human donors were unrelated Air Force personnel, originally from different parts of the United States, and of diverse HLA types. Because of limited availability of blood, only 13 of the HIV+ donors could be HLA-typed, and only 8 could be typed for DR and DQ, which require more blood (Table 5). In this limited sample, no correlation between response to any peptide and any HLA type could be detected. We conclude that all of these cluster peptides fulfill the hypothesis that peptides which are broadly recognized by murine T cells are likely to be broadly recognized by human T cells as well. Indeed, some of the peptides, such as cluster peptides 1 and 5, were more broadly recognized by humans of diverse HLA types than by different strains of inbred mice tested.

The results in Table 3 indicate that 31 (86%) of the 36 donors responsive to the positive control antigen flu who were tested with at least three peptides responded to at least one of them. To

5 further test the extent of the population that could respond, an additional 13 HIV-seropositive donors responsive to flu, not overlapping with the donors listed in Table 3, were tested for their response to  
10 a mixture of the six cluster peptides, each at 2.5  $\mu$ M. Ten of these 13, or about 77%, responded, whereas none of four seronegative donors responded to the mixture of peptides, although all four responded to flu. Although it is possible that the peptides in the mixture may compete with each other for binding to some MHC molecules, given the small sample sizes in the two groups studied, there is probably not a statistically significant difference between the fraction responding to at least one peptide in the 15 first group and the fraction responding to the mixture in the second. In either case, we conclude that a sizable majority of people are capable of making T cell responses to these peptides.

20 6. Immunization with peptides to induce T cells responding to intact gp160 in vitro.

25 If the peptides identified by the two screening techniques above are to be useful components of a vaccine, it is important that they not only be recognized by T-cells immune to the HIV envelope protein gp160, but also that they be immunogenic to elicit T cells in vivo that can respond to gp160. Of course, the immunizations cannot be performed yet in the clinically relevant species, (uninfected) humans, but it is desirable to be sure that for the strains of mice shown above to have T cells responsive to these peptides, the mice can be immunized in vivo with the peptides and elicit T cells that respond to intact

gp160 in vitro. Each peptide is tested by immunizing mice of the strain responding best to that peptide based on the data in Fig. 1. Mice of the four strains shown are immunized subcutaneously in the tail with 5 8-10 nmoles of the indicated cluster peptide in a 1:1 emulsion with CFA, final volume per mouse 50  $\mu$ l except for cluster peptide 2 which was in 75  $\mu$ l. Twelve days later, the draining lymph nodes are harvested from 2 mice of each group (strain and peptide combination) 10 and assayed as described above. Results are shown as stimulation indices, the ratio of experimental cpm over cpm from stimulation with medium alone, which ranged from 3000-7000 cpm for the different groups.

15 B10.BR mice immunized with cluster peptide 1, cluster peptide 5, or cluster peptide 6 all produced T cells that could be stimulated by recombinant gp160 in vitro (Fig. 2, panel A). As a control for possible mitogenicity of the recombinant gp160, T cells from B10.BR mice immunized with only complete Freunds adjuvant did not respond significantly to the gp160 in 20 vitro (Fig. 2, panel A). Therefore, the in vitro response was a result of immunization with the peptides. Similarly, T cells from B10.S(9R) mice immunized with either cluster peptide 3 or cluster peptide 4 responded to recombinant gp160 in vitro, whereas similar mice immunized with adjuvant alone 25 made a weak (mitogenic) response at only the highest concentration (Fig. 2, panel B). Likewise, B10.A(5R) mice immunized with cluster peptide 6 and B10.D2 mice immunized with cluster peptide 2 produced T cells 30 responsive to gp160 in vitro (Fig. 2, panels C and D). All of these responses show high dose inhibition typical of T-cell proliferative responses, but in this

case the decreased resp ns at 30  $\mu$ g/ml also may be due to some toxicity of the recombinant gp160 preparation, which was solubilized in 8M urea and sodium dodecyl sulfate. Although the gp160 was dialyzed before use, it is possible that residual detergent that is hard to remove was toxic at the highest dose. Nevertheless, the clear response at 10  $\mu$ g/ml in all cases indicates that all six cluster peptides elicit in vivo T cells that can react with gp160.

Example 2

Use of cluster peptides in a diagnostic assay for HIV-1 infection of patients

The cluster peptides described in Table 1 above may be utilized for the diagnosis of HIV-1 positive seroconversion in patients. The detection of HIV-1 gp160 specific T cell responses to these peptides can be accomplished by standard techniques of T-cell proliferation and production of IL-2 or other lymphokines as described above in Example 1, items 4 and 5, applied to humans as described in Clerici et al., Nature, Vol. 339, pp. 383-385 (1989).

Alternatively, the diagnostic test can be of a cytotoxicity format as described for the peptide env-K<sub>1</sub> in Berzofsky, et al., U.S. patent application Serial Number 07/148,692. This format has the advantage of detecting infected individuals that are not yet producing antibodies to HIV.

Example 3

Chemical modification of the cluster peptides to enhance their pharmacologic characteristics

5        Small peptides circulating in the blood are subject to degradation by proteolytic action and clearing by the kidneys. Yet, a number of naturally occurring peptides are found in the circulation, for example the enkephalins. These small peptides are often found to be modified by amidation of the carboxy-terminus (Kitamura, K. et al., *Biochem. Biophys. Res. Comm.* 169:1164-1171 (1990); Dickson, C.J. and Yamada, T., *J. Biol. Chem.* 266:334-338 (1991)). Thus, it may prove advantageous to produce chemically modified variants of the cluster peptides for use in therapeutic applications. The enzymatic carboxy-terminal amidation of a synthetic peptide has been described (Suzuki, K. et al., *EMBO J.* 9:4259-4265 (1990); Katopodis, G.A. et al., *Biochemistry* 30:6189-6194 (1991)). Also, the addition of residues useful for the cross-linking of the peptides to carrier proteins for immunizations or to solid supports for immunoassay or antibody purification applications may prove advantageous. Many means for chemical modification of peptides are well known in the art.

20       The peptides of the instant invention could also be coupled to, or co-synthesized with, peptides that bind to or induce production of neutralizing antibodies to HIV or cytotoxic T-cells specific for HIV. The peptides of the instant invention serve as HIV I-specific carriers in such constructs, which advantageously induces a memory in T-cells which would cause a memory helper T-cell response on exposure to HIV, in contrast to the use of HIV-unrelated carriers which would not produce such a memory response on exposure to the virus. Useful HIV-I specific carriers are, for example; as described in Good, M.F. et al.,

Science, Vol. 235, pp. 1059-1062 (1987); U.S. Patent No. 4,886,782 to Good et al.; and Parker, T. J. et al., J. of Immunology, Vol. 142, pp. 3612-3619 (1989), which are hereby incorporated by reference.

5

Example 4Administration of cluster peptides as a vaccine against HIV-1

The aim of the research of a large number of biomedical researchers is the production of a vaccine which would produce protection to humans from infection by HIV-1 or therapeutic benefit in AIDS treatment. The instant invention provides a means for identifying peptides that may prove useful as such vaccines as well as specifying six particular peptides as candidates based on the production of a T-cell response to the protein target from which the peptides are derived in mice immunized with the peptide. A pharmaceutical composition including a vaccine in accordance with the present invention comprises an effective antigenic or therapeutic amount of at least one of the cluster peptides and a pharmaceutically acceptable carrier such as physiological saline, non-toxic, sterile buffer and the like. Of course, additives such as preservatives, sterilants, adjuvants and the like, well known to one of ordinary skill in the art, could also be included in the pharmaceutical composition to maintain or increase the efficacy of the preparation.

It is proposed that peptides of the instant invention can also be administered as a vaccine in a fashion similar to that for the administration to primates of a synthetic peptide vaccine against

hepatitis B as described by Itoh (Itoh, Y. et al., *Proc. Natl. Acad. Sci. USA* 83:9174-9178 (1986)). An alternative method for the preparation of vaccines involves the use of Protein A coated microbeads that bind immune complexes of an antibody and the immunizing antigen on their outer surface described for example in Platt, et al., U.S. patent number 4,493,825, hereby incorporated by reference. In addition, the cluster peptides of the invention could be coupled to, or conjugated with, peptides that bind to or induce.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

ClaimsWhat is claimed is:

1. A process for the identification of peptides useful for subunit vaccines against HIV that comprises:
  - 5 (i) production of vaccine candidate peptides, the amino acid sequences of which represent fragments or mimetopes of a larger target protein, by chemical synthesis or the use of recombinant DNA technology;
  - 10 (ii) immunization of congenic mice, differing in MHC haplotype, with the complete protein target of the peptide vaccine;
  - 15 (iii) production of lymph node suspensions from the immunized mice and testing of the proliferative response of the T-cells therefrom to challenge with the candidate vaccine peptide;
  - 20 (iv) isolation of peripheral blood lymphocytes (PBL) from a population of HIV seropositive human donors, of such size as to be useful for statistical evaluation;
  - 25 (v) testing of said PBL for interleukin-2 production in response to a control memory antigen, and testing for interleukin-2 production by the PBL in response to challenge with the candidate vaccine peptide;

(vi) selection of those peptides that produce a significant response in both of steps (iii) and (v) for use in immunization of mice;

5 (vii) testing of the proliferative response of T-cells isolated from the immunized mice of step (v) to challenge with the whole target protein; and

(viii) designation of peptides producing statistically significant positive responses in step (vii) as candidate vaccines.

10 2. A vaccine against HIV comprising peptides selected by the process of claim 1, wherein the mice used in step (ii) are of the strains B10.BR/SgSn, B10.D2/nSn, B10.S(9R) and B10.A(5R)

15 3. A vaccine against HIV comprising peptides selected by the process of claim 1, wherein the target protein is HIV glycoprotein 160 (gp160).

4. A vaccine against HIV comprising peptides selected by the process of claim 2, wherein the target protein is HIV gp160.

20 5. A peptide comprising the amino acid sequence EQMHEDIISLWDQSLKPCVK.

6. A peptide comprising the amino acid sequence FVTIGKIGNMROAHCNISRAKWNNTLKQIDSKL

25 7. A peptide comprising the amino acid sequence KQIINMWQEVGKAMYAPPISGQIR.

8. A peptide comprising the amino acid sequence  
RDNWRSELYKYKVVKIEPLGVAPT.

9. A peptide comprising the amino acid sequence  
RIVELLGRRGWEALKYWWNLLQYWSQELKNSAVS.

5 10. A peptide comprising the amino acid sequence  
AVAEGETDRVIEVVQGAYRAIRHIPRRIRQGLER.

11. A peptide vaccine against HIV comprising at  
least one peptide selected from the group consisting  
of the peptides recited in Table 1.

10 12. The peptide according to claim 11, which has  
been covalently modified by derivatization with a  
small moiety to achieve better pharmacologic  
characteristics than obtainable by the underivatized  
peptide, or other minor modifications which do not  
15 undesirably alter the activity of said peptide.

13. A vaccine against HIV which comprises at  
least one peptide selected from the group of peptides  
recited in Table 1, and a pharmaceutically acceptable  
carrier.

20 14. A vaccine against HIV according to claim 13  
comprising a mixture of at least two of the peptides  
recited in Table 1 and a pharmaceutically acceptable  
carrier.

15. A kit for the diagnosis or prognosis of HIV  
25 which comprises at least one of the peptides recited  
in Table 1.

16. A method for the diagnosis or prognosis of HIV comprising the use of at least one of the peptides recited in Table 1 in an assay.

17. A method according to claim 16, wherein said assay measures T-cell proliferation, or production of IL-2 or other lymphokines.

18. A method for the therapeutic treatment of HIV which comprises the administration of a formulation according to claim 14 to a HIV seropositive patient.

19. A construct which comprises at least one of the peptides recited in claims 5-10 and 12 coupled by chemical coupling or co-synthesized with a second peptide containing a T- or B-cell epitope.

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FIG. 1A

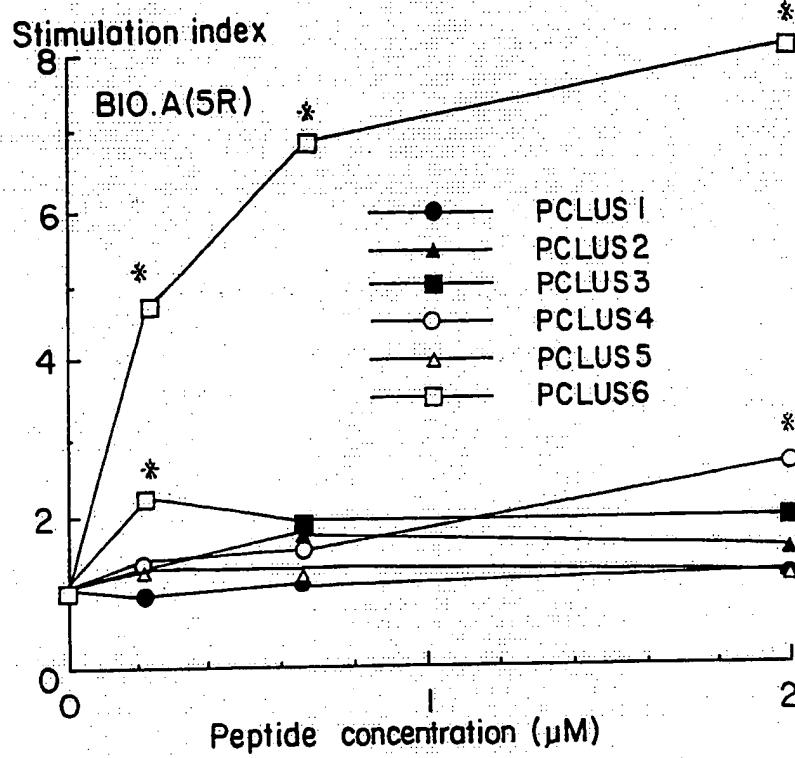
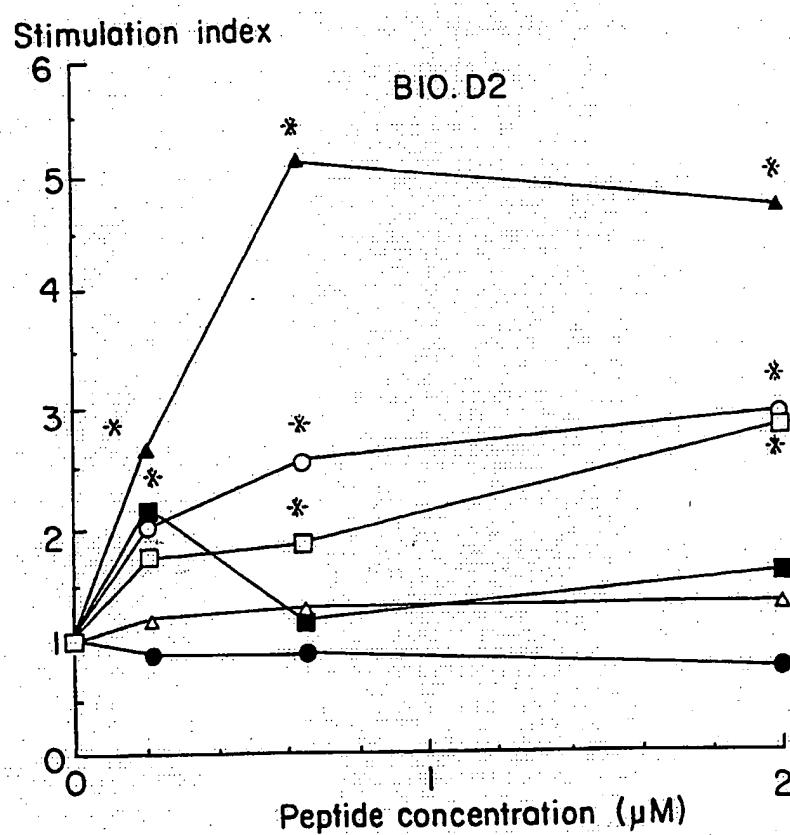
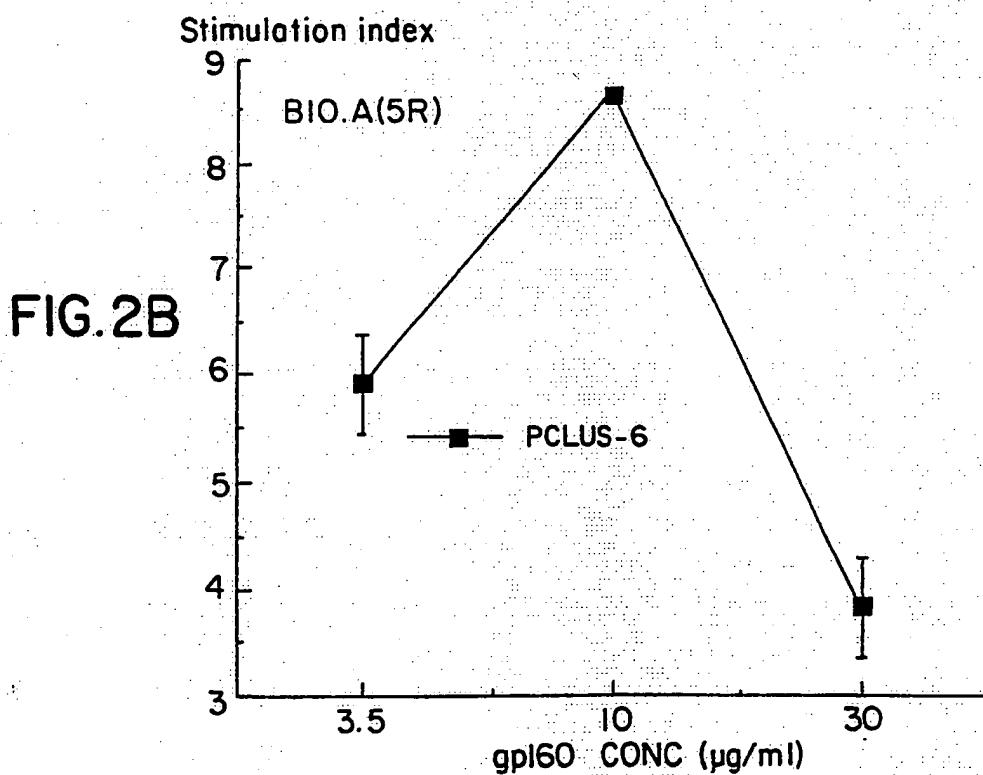
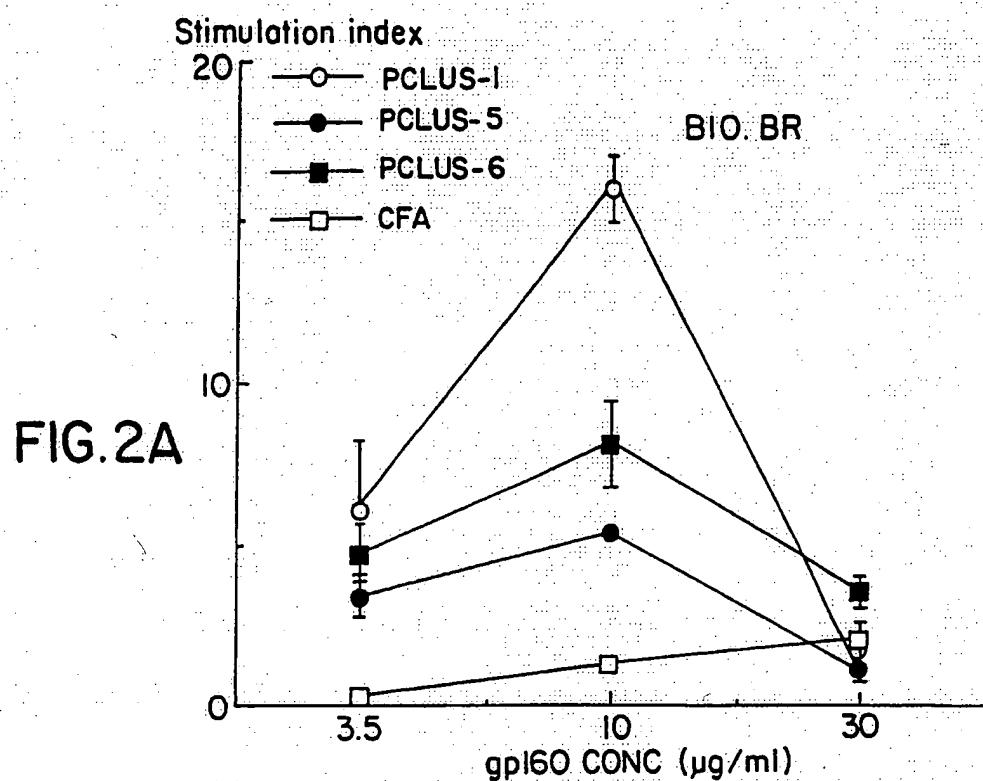


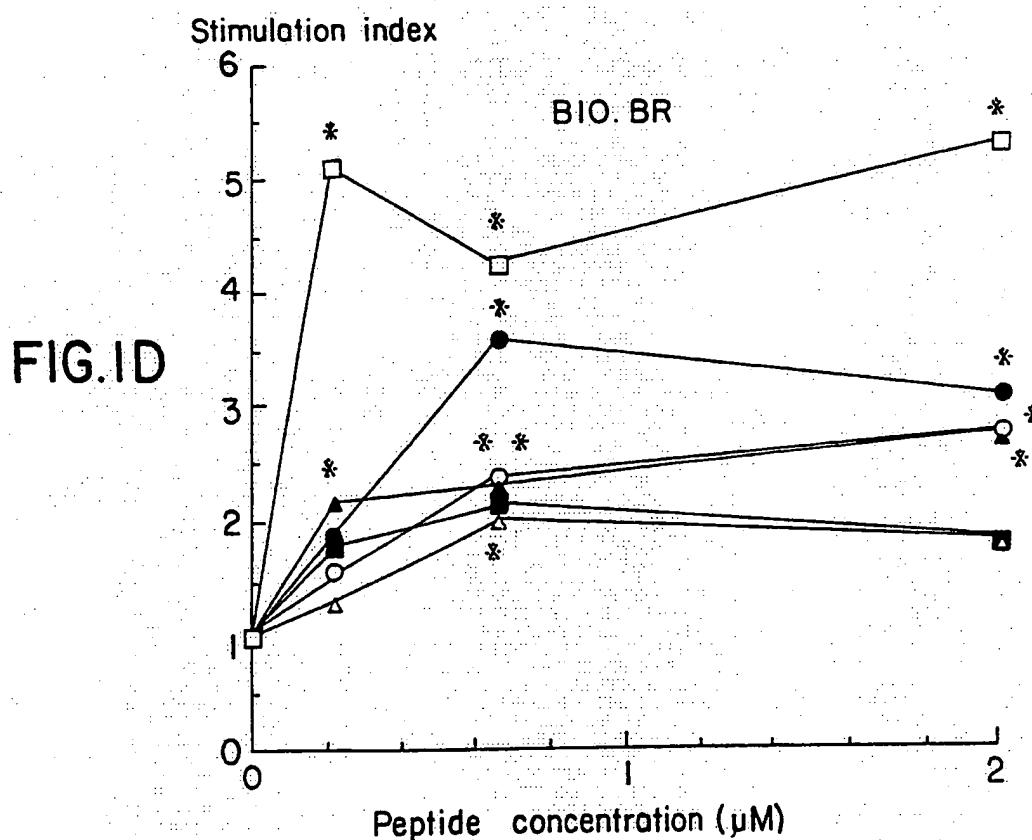
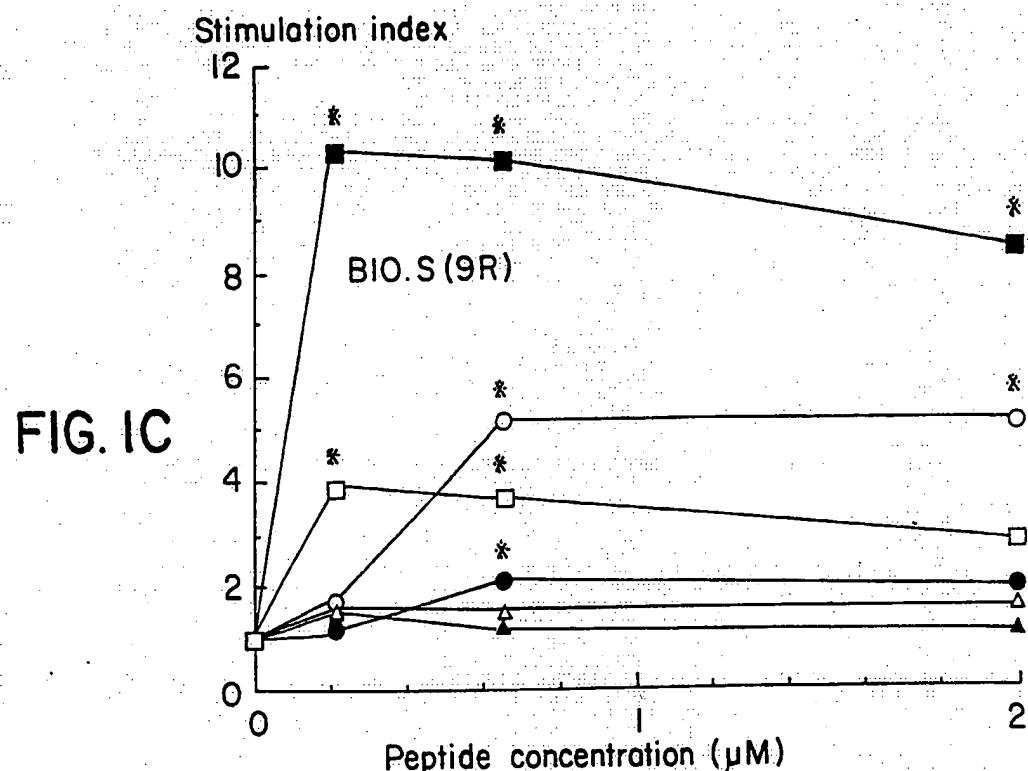
FIG. 1B



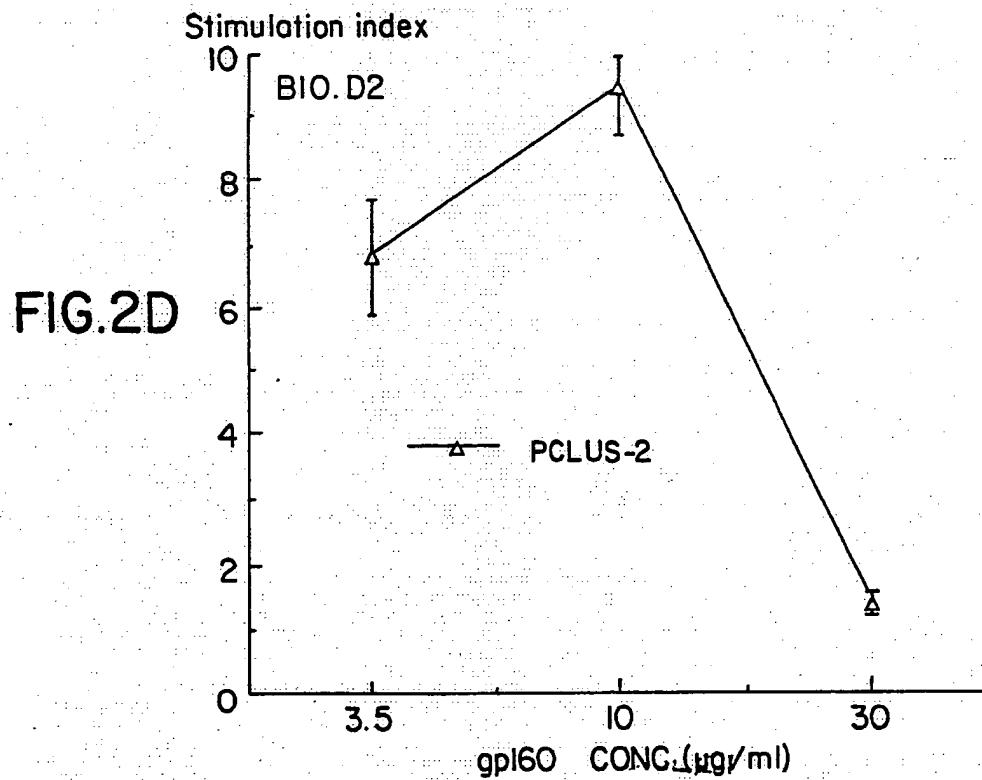
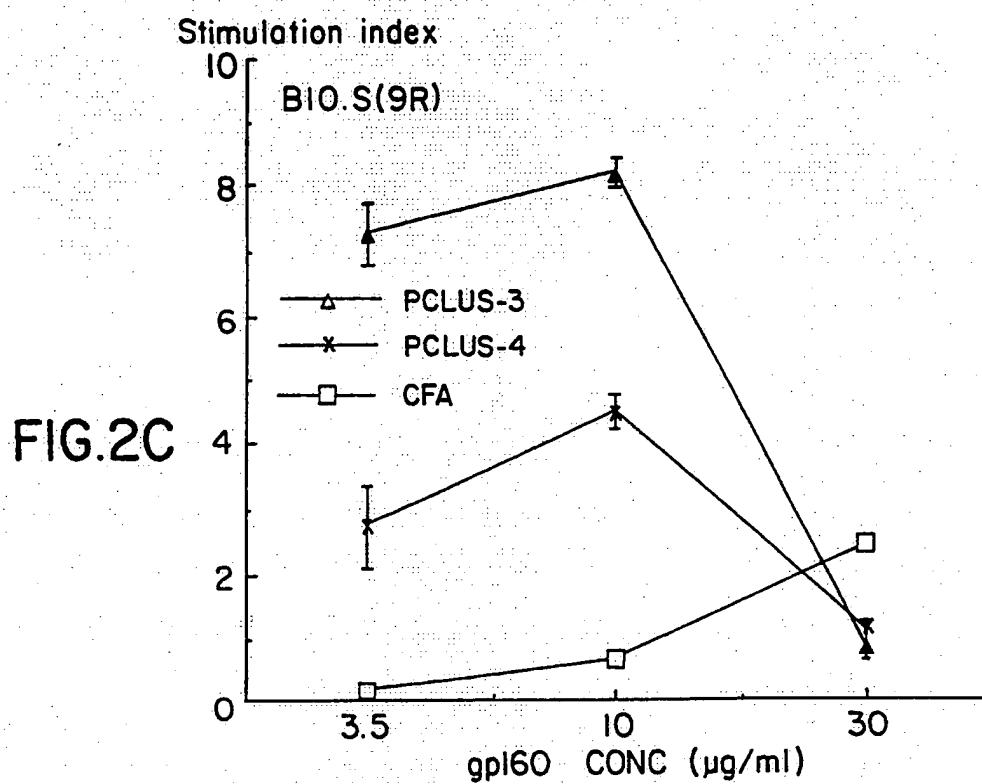
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**SUBSTITUTE SHEET**

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**SUBSTITUTE SHEET**

4/4



# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US92/07422

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :Please See Extra Sheet.

US CL :424/89; 530/324, 326; 435/7.21

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/89; 530/324, 326; 435/7.21

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, Dialog, search terms: HIV, peptide, T-cell stimulation, vaccine

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Proceedings National Academy of Sciences, volume 84, issued June 1987, Cease et al, "Helper T-Cell Antigenic Site Identification in the Acquired Immunodeficiency Syndrome gp120 Envelope Protein and Induction of Immunity in Mice to the Native Protein Using a 16-Residue Synthetic Peptide", pages 4249-4253, see entire article.	1-14
Y	Nature, Volume 334, issued 25 August 1988, Berzofsky et al, "Antigenic Peptides Recognized by T Lymphocytes from AIDS Viral Envelope-Immune Humans", pages 706-708, see entire article.	4-11 and 15
Y	Nature, Volume 339, issued 01 June 1989, Clerici et al, "Interleukin-2 Production Used to Detect Antigenic Peptide Recognition by T-Helper Lymphocytes from Asymptomatic HIV-Seropositive Individuals", pages 383-385, see entire article.	16-19
X	US, A, 4,943,628 (Rosen et al)24 July 1990, columns 2-12.	1-19

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

06 October 1992

Date of mailing of the international search report

24 NOV 1992

Name and mailing address of the ISA/  
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LYNETTE E SMITH

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US92/07422

**A. CLASSIFICATION OF SUBJECT MATTER:**

IPC (5):

IPC(5):A61K 39/12, 37/02; C12Q 1/00; C07K 5/00, 7/00, 15/00, 17/00